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BACKGROUND DOCUMENT

# AUTOMOTIVE LABORATORY INSTRUMENTATION

## 1. INTRODUCTION

Automotive laboratory instrumentation may be divided into the five broad classifications, power absorption and measurement, temperature measurement and control, pressure measurements, fluid flow, and dimensional measurement. Many of these instruments find application in other fields and are discussed only in sufficient detail to indicate their functioning for the specific application. Specialized instruments are discussed in reasonable detail; however, a handbook dealing with the specific instrument should be consulted for any particular application.

Webster defined a dynamometer as "an apparatus for measuring power". The more general or common usage of the term includes the ability of the apparatus to absorb or to produce power, accomplished by an absorption and motoring dynamometer respectively. However, it must be emphasized that these functions are not essential; the dynamometer may merely transmit power. With few exceptions, all dynamometers operate on the same basic principle; an apparatus capable of absorbing, producing, or transmitting power is cradled (mounted so that its housing is free to turn in bearings about the center of the input-output shaft) and the reactive force (the force tending to spin the housing) is measured. Figure 1 is a simple sketch of such a unit; it may be an electric or hydraulic unit, or the rotor may be the gears of a transmission. The operating principles for a few dynamometers, such as the Prony brake and torque tube types, are not identical with those described above since they are not cradled. They do, however, measure the reactive force. One notable exception to the concept of reactive force measurement is found in the strain gaged shaft, where the strain induced in the shaft by an applied torque is measured.

Any prime mover that can be cradled may be used for a motoring dynamometer. The most common is a shunt-wound electric motor although smaller units use hydraulic motors. While gasoline engines have been cradled and used successfully, this method is not considered the most satisfactory because of its many variables(e.g., vibration, heat and mechanical complexity). It is recommended only when standard dynamometers are not available.

The first two motoring units mentioned above may be used for absorption, the electric motor becoming a generator and the hydraulic motor becoming a pump. With this method, input power is transformed into another form of energy; a means for controlling the "load" and expending the energy must be provided. Variable resistor-load banks,utilizing air cooling, are the simplest means of expending energy for an electric dynamometer. The hydraulic pump requires suitable throttling devices for applying and controlling the load and a heat exchanger to remove the heat absorbed by the working fluid. For simple absorption, the Prony brake, water brake, and eddy-current dynamometer are the most common. The Prony brake is limited to low speed and relatively low capacity. Its function

* Supersedes OPM 80-31

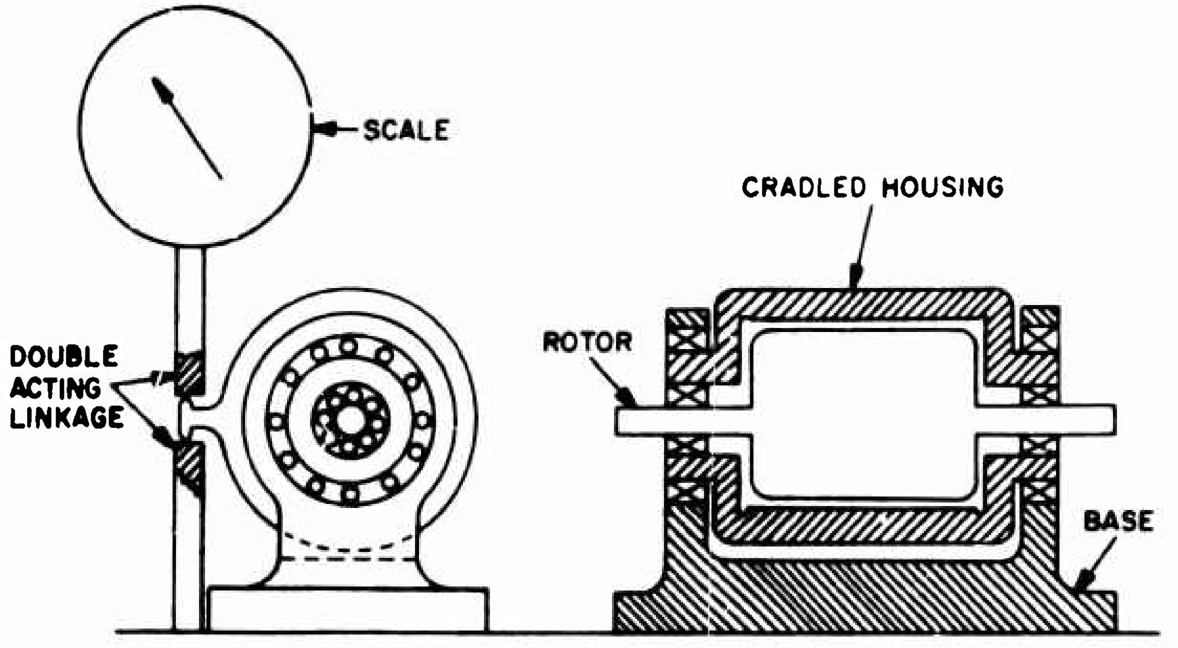


Figure 1. Schematic of Typical Cradled Dynamometer. The Reaction torque between the rotor and the housing (the force tending to spin the housing) is measured on the scale which restricts the travel of the housing.

depends on the mechanical friction between a brake surface and a flywheel. The water brake is simply a pump; an inefficient centrifugal pump gives the best results as a dynamometer. Eddy current dynamometers are fundamentally magnetic brakes. A rotor, turning in a magnetic field, generates an electric current. Instead of being dissipated normally through brushes as in a generator, the currents are allowed to flow at random within the windings, eventually dissipating as heat which in turn is removed by water flowing through the dynamometer.

The method for measuring force is not directly related to the dynamometer. Any scale, having an adequate range and with an accuracy of ± 2 percent, will suffice. A springless scale is preferable. A double-acting linkage is essential so that rotation of the dynamometer in either direction is possible. In some installations, remote reading of the scale is desired. This may be achieved by means of hydraulic, pneumatic, or electric transmitting devices, or by a strain-engaged link.

Torque and power are related to speed. In all dynamometer testing, it is necessary that speed as well as force be measured. For ease of operation, an indicating tachometer is required; for accuracy consistent with the other instrumentation used in dynamometer testing, a time-count system should be utilized. In this, a revolution counter accurate to ±1 revolution per minute is automatically controlled over a fixed time period (usually a 1/10 or 1 minute period). Various forms of hand tachometers and stroboscopic lights find use in special applications but generally lack either simplicity of operation or accuracy.

This test procedure provides basic information on the various types of laboratory dynamometers and instrumentation associated with engine, transmission, and other power train component testing. Separate MTP sections deal with the actual test which may be conducted, indicating the general procedure and the type of information which may be obtained.

## 2. TECHNIQUES

### 2.1 TEMPERATURE MEASUREMENT AND CONTROL

In testing power train components, the measurement of temperature is required. The output of the test item is often influenced by ambient temperature and requires a correction factor; efficiency may be a function of component temperatures; a thermal heat balance of the flowing fluid may be of importance as a measure of efficiency; and the life of the many parts may be closely associated with operating temperatures.

A simple mercury thermometer provides a means for obtaining much data but its application is limited. Normally, remote indication is preferred in testing of engines and transmission. Thermocouples are generally suited for remote temperature indication, since they neither interrupt the fluid flow pattern nor present sealing problems. For general automotive purposes, the iron constantan thermocouple has been found to be best for normal temperature use; chromel-alumel thermocouples are used in exhaust gas and other high temperature applications. An indicating device which will give a readable accuracy of ±2° F for temperatures below 1000° F and ±10° F above 1000° F is required. Except for special applications, recording devices are unnecessary. Where a large number of readings are being made, a multi-channel, push button, self-balancing indicator is desirable; otherwise, a simple selector switch coupled to a pyrometer-potentiometer is satisfactory. A portable direct-reading pyrometer is often convenient in determining critical points for the installation of thermocouples.

There are special problems which must be considered although they are generally not applicable in automotive testing. When measuring the temperature of flowing fluids, the impact of the fluid on the sensing element will cause the element to indicate the total temperature instead of the static temperature. Velocities such as found in gas turbines make it necessary to account for this impact effect. When measuring extremely high temperatures, the effects of radiation must also be considered. The sensing element may receive heat or lose it to surrounding bodies due to radiation, thus giving a false temperature reading.

Shielding may be used to eliminate the effects of radiation but such shielding should not be confused with that used for corrosion and erosion protection. Reference 1 discusses these problems in detail.

One of the more important temperatures in the engine cycle is developed in the combustion chamber. This temperature is not easily measured. Research techniques have been developed but they are not applicable to routine testing. An indication of the average combustion chamber temperature is obtained by imbedding thermocouples in the spark plug gaskets and head bolt washers.

It is frequently desired to control as well as to measure temperature. A thermostat and heat exchanger are required for this function and should be selected on the basis of the job requirement. Manufacturer's catalogs and heat transfer text books are suggested as further sources of information.

## 2.2 PRESSURE MEASUREMENT

Most of the instrumentation in this field requires standard techniques. Pressure gages and manometers provide the means for indication. Manometers are generally more accurate but do not lend themselves to the measurement of a wide range of pressures. A pressure gage with a large mirrored dial may provide equivalent accuracy with greater range but at a greater cost.

Unlike temperatures, combustion chamber pressures may be determined on production engines. A special spark plug with a quartz, pressure-sensitive element is used. This plug must closely match the characteristics of the standard plug. The output of the quartz crystal is fed through amplifiers to an oscilloscope on which instantaneous or mean effective pressure may be determined.

## 2.3 FLUID FLOW

Problems of fluid flow, both gas and liquid, are varied. Generally speaking, the principles that are applied to any fluid may be applied to the other. The fluids most commonly encountered in power plant testing are gasoline for fuel oil, lubricating oil, hydraulic oil, water, air, and exhaust gas.

The basic standards for measuring fluid flow are the nozzle, orifice, and pitot tube. These require certain line configurations which are sometimes difficult to obtain in practice and involve time consuming computations. Reference 2 is suggested for further details.

The tapered tube flow meter, commonly known as the rotameter, is more generally used because it permits direct reading of data. However, since this instrument is sensitive to specific gravity and viscosity, care must be used in applying it to flow problems. Where specific gravity and viscosity remain constant and the calibrated flow meter is used, data accurate to ±.5 percent may be expected.

A common method for metering liquids is the weight-time system. This is usually considered an absolute method but is subject to errors if not properly designed. The force of the falling liquid and the care of hose connections must be considered.

Exhaust gas analysis, although qualitative, can indicate flow rates through the fuel-air ratio. An Orsat analysis yields information but is unwieldling and does not give direct data. A preferred system is one in which a sample of the exhaust gas is passed through an analyzer, where one portion of gas is burned in the presence of hydrogen and another in the presence of oxygen. the energy released creates an unbalance in bridge circuits, which indicate the quantity of oxygen and combustibles present.

2.4 DIMENSIONAL MEASUREMENTS

With but few exceptions, the instruments and gages used to measure engine, tranmission, or component wear are standard shop type items (e.g., micrometer, snap gages, etc.) They differ only in the degree of accuracy to which they determine the dimension. An effort should be made to read to the nearest 0.001 inch.

Johansson gage blocks and ring gages are required for a continuing check of the gage calibration. A constant temperature should be maintained in the inspection room.

Weights are determined with an analytical balance. For parts such as rings and bearings, weight is determined to the nearest 0.0001 gram; for larger parts, accuracy to 0.0005 or 0.001 gram may be sufficient.

The McKee wear gage determined very small amounts of cylinder wear (0.00025 inch on the radius). A diamond tool makes a tiny "V" impression in the surface of the barrel. By means of a microscope and prism arrangement, the dimesion across the apex is determined (Figure 2). As wear occurs, the dimension across the apex of the "V" decreases and may be measured at the end of the test.

3. DATA REUDCTION AND PRESENTATION

There are many instruments commonly referred to as engine analyzers, but the following description is limited to a group of electronic instruments used to evaluate engine performance. This evaluation is made by determining malfunctioning of the ignition system, improper technical timing, and faulty combustion while the engine is operating. For the first of these, data are obtained by capacitive pickups on the ignition harness which feed am amplifier and oscilloscope. Timing data are obtained by feeding into an oscilloscope the output of a special vibration pickup mounted on the flywheel. Combustion is determined by mounted pickups on the engine head and feeding the output into an oscilloscope. In all three cases, interpretation of results is accomplished by comparing traces obtained with standard traces and analyzing them in terms of engine function.

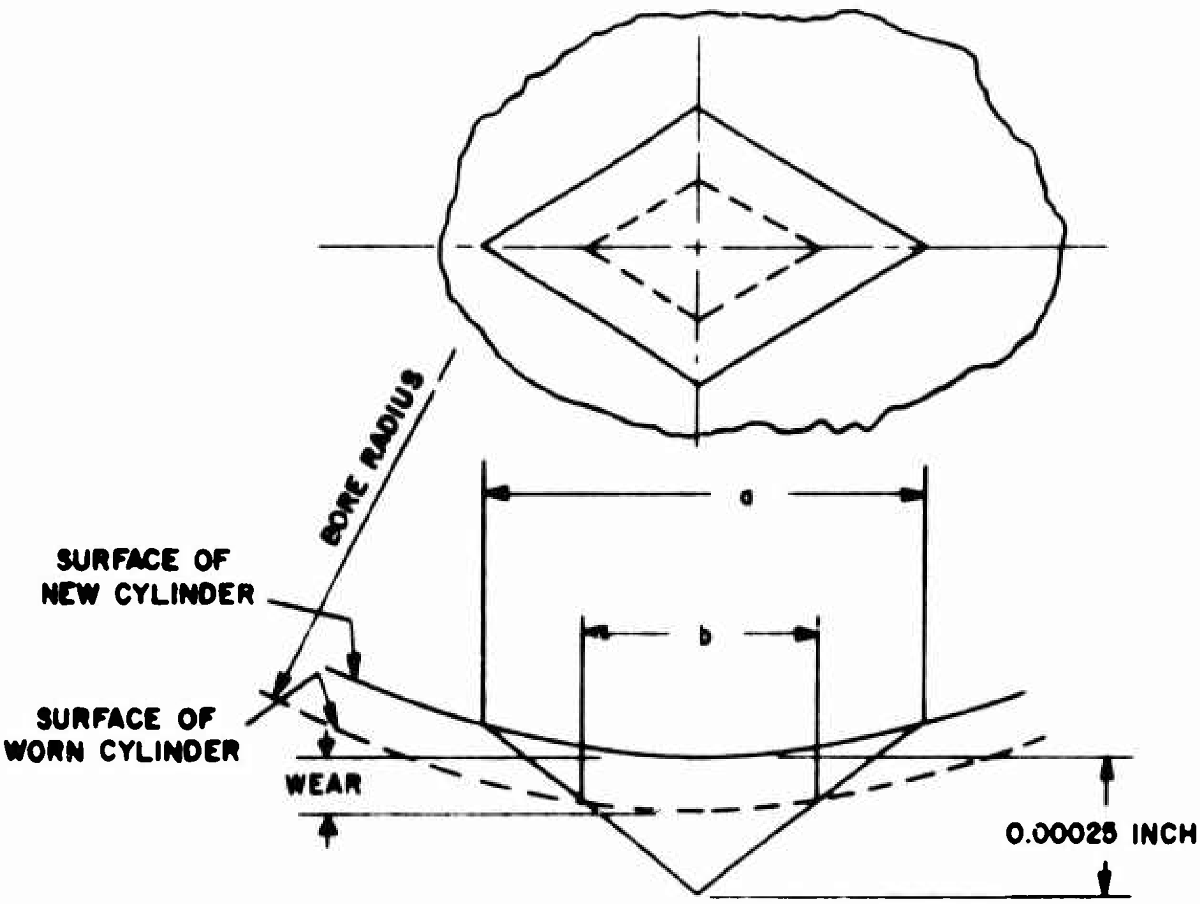


Figure 2. McKee Wear Gage - Effect of Wear on "V" Indentation

a. Dimension determined before test.
b. Dimension determined after test wear-increase in bore diameter is a function of the difference between a and b and is determined from a chart.

## REFERENCES

A. Ernest F. Frock and Andrew I. Dahl, Temperature Measurements in High Velocity Streams of Hot Gas, National Bureau of Standards Report No. 3164. U. S. Department of Commerce.

B. ASME Research Publication, Fluid Meters, Their Selection and Installation, The American Society of Mechanical Engineers, 29 West 39th Street, New York, New York.